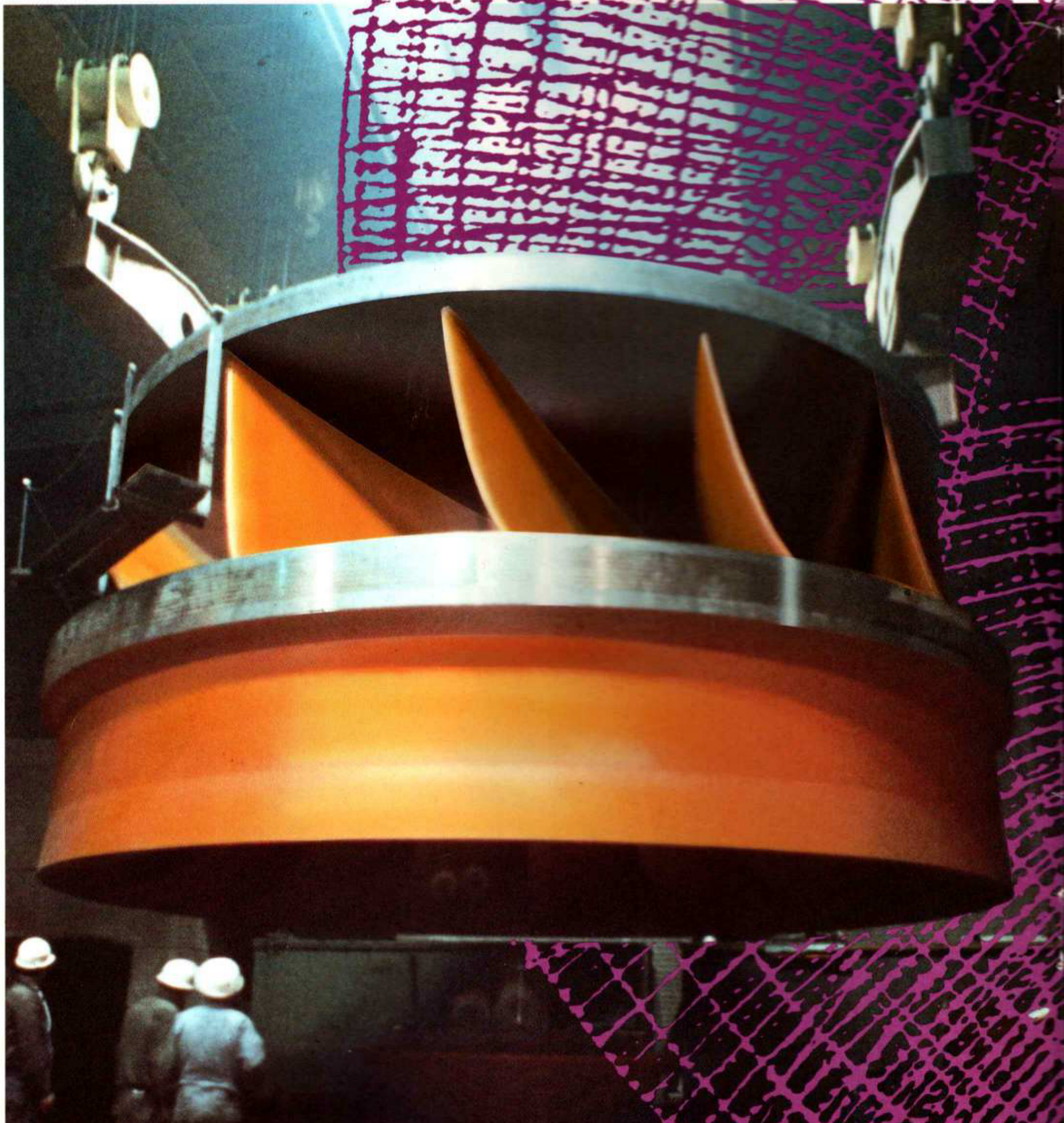
GE Canada

Hydraulic Turbines

Lifting a 500 ton Francis runner for one of the three 612 MW hydraulic turbines designed by GE Canada for the Grand Coulee Project. These units are among the world's most powerful turbines.



Leadership in hydraulic turbine technology

Through its Dominion Engineering Works Division, GE Canada has played a leading role in the manufacture of hydraulic turbines for the growing hydroelectric power industry since the early 1920's. This leadership is demonstrated by the many significant achievements of the Company in the turbine field, by the quality of the machines produced and by the modern manufacturing and world-class testing facilities which have been established.

The Company has earned a special place in the history of water power development in Canada . . . over half of the country's current installed capacity of 57,945 MW is powered by turbines manufactured by GE Canada. The Company's record of achievement also includes a significant number of world firsts.

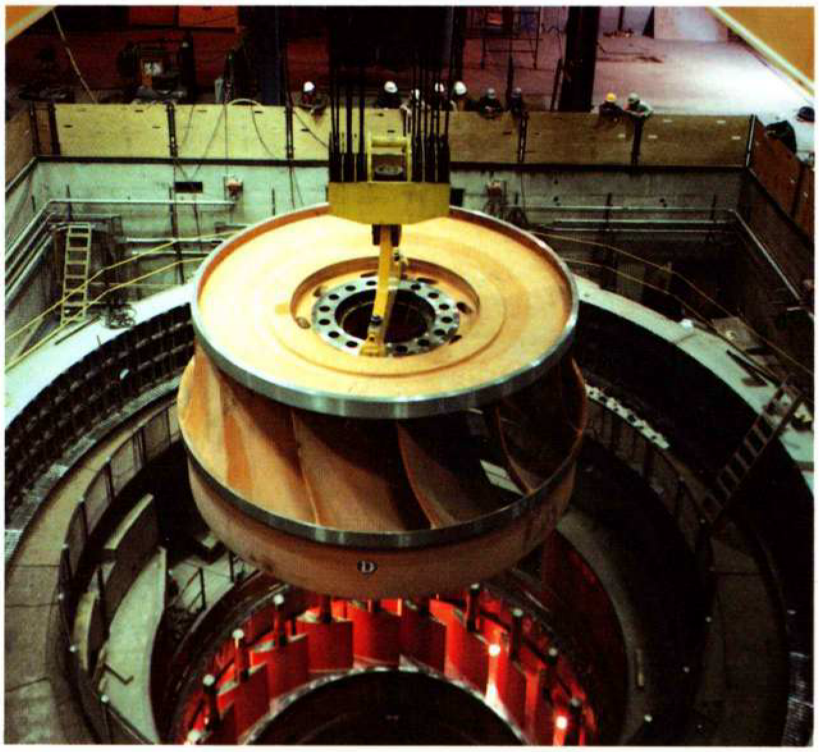
During the thirties, GE Canada produced the world's largest and most powerful propeller turbines. More recently, the Company again attained recognition as a leader in propeller turbine technology by producing the four 142 MW propeller turbines for the Rocky Reach hydro project in the USA. In 1954 and again in 1960, GE Canada built four Pelton turbines, the highest powered turbines of their kind in the world. Between 1971 and 1974 the Company produced five Francis turbine units rated at 483 MW for the Churchill Falls (Labrador) Corporation. They were the highest powered turbines in the world outside the USSR.

Between 1974 and 1975, these machines were overtaken by the Company's three Francis turbines designed for the Grand Coulee hydro project on the Columbia River in the USA. These giants were rated at 612 MW each, the highest power rating of any turbine anywhere in the world.

A substantial part of GE Canada's business over the years has been derived from international sales to Brazil, Colombia, Bolivia, New Zealand, Pakistan, India, Sri Lanka, Jamaica and the USSR, as well as to the United States. Today, GE Canada turbines are operating in almost 300 major hydro projects worldwide. Total capacity installed or on order is in excess of 38,000 MW.

GE Canada's commitment to provide leading-edge technology on each project ensures that the Company will continue to play a paramount role in the hydraulic turbine field.

Achievements . . . the foundation of the future

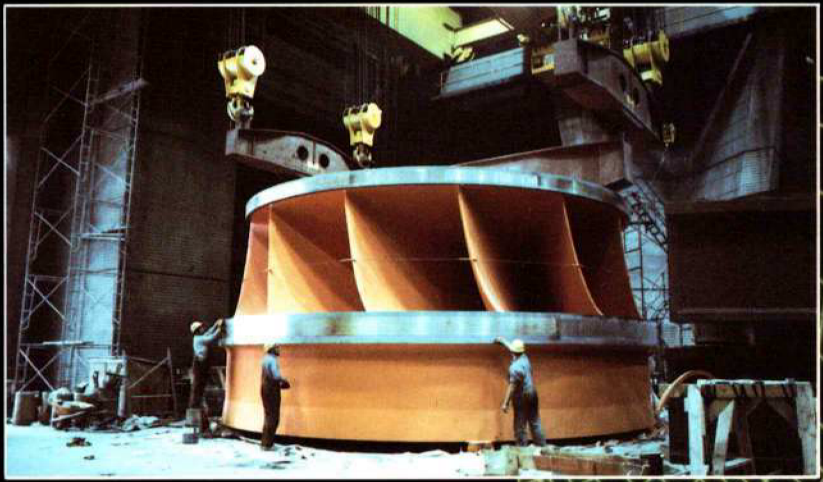


One of twelve 195 MW Francis turbines supplied by GE Canada for the La Grande 3 Powerhouse.

Francis Turbines

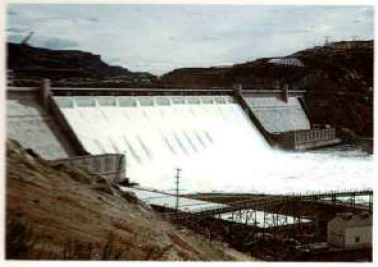
GE Canada has supplied over 400 Francis turbines, totalling more than 20,750 MW of installed capacity, to domestic and international customers since manufacturing began in the 1920's. The most spectacular of these machines in physical size, rated output and unique methods of construction and erection are the three giant units built for the Grand Coulee project in the USA. These units have runners over 10 metres in diameter, weigh over 500 tons and are each capable of producing an output of more than 1,000,000 HP, placing them among the largest ever built. The size of these machines, the remoteness of the site and the limited transportation facilities available meant that much of the assembly and subsequent work on the major components had to be done on site. This necessitated the building of a massive fixture to facilitate assembly and welding of

Grand Coulee runner prepared for site stress relieving.



Propeller turbine replacement runner for the modernization program at Hydro-Québec's Rivière des Prairies Generating Station.

US Army Corps of Engineer's R.B. Russell Dam.



GE Canada manufactured eight 127 MW Francis turbines for Hydro-Québec's Manicouagan 2 Project.

the runner, the installation of an on-site heat treating furnace for stress relieving, and the design and construction of a special boring and milling machine to finish the runner. These, and the many other new design concepts and production methods developed and proven on this project, pave the way for even larger machines in the future. In addition, the results of tests conducted at each stage of installation provide GE Canada with an invaluable data base for the design of future giant- and conventional-sized turbines.

GE Canada has also played a significant role in the La Grande Complex of the Société d'énergie de la Baie James, one of the world's largest hydroelectric power developments. Eight Francis turbines rated 339 MW at a design head of 137.1 metres were supplied for the underground LG2 powerhouse and twelve units rated 195 MW at a design head of 79 metres were supplied for the LG3 powerhouse. Ring gates were also supplied for the LG2 turbines.

A number of large Francis turbines have been produced by GE Canada for Hydro-Québec. These include five 134 MW units for Bersimis 2, eight 127 MW units for Manicouagan 2 and six 200 MW units for Manicouagan 3. The model for the latter turbines established a world record for efficiency at the time it was tested, exceeding 94%.

Other noteworthy GE Canada Francis turbine installations are the five machines for Churchill Falls rated 483 MW under a head of 313 metres, the most powerful and highest head turbines in Canada, and the three machines for Alto Anchicaya, Colombia, rated 118 MW under a head of 400 metres, among the highest head Francis turbines in South America.

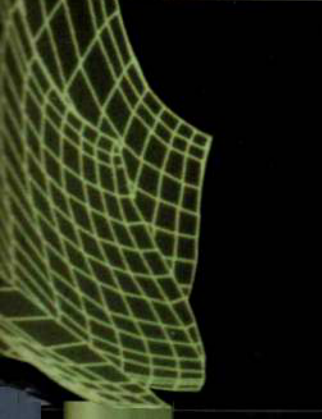
Propeller Turbines

GE Canada has played a leading role in propeller turbine design, development and manufacturing since the early 1920's when the Company produced the then world's largest unit, a 24 MW machine designed to operate under a head of 18 metres. Other world-class propeller turbines designed and built by GE Canada include the four machines rated 142 MW at a design head of 26.4 metres produced for the Rocky Reach project in the United States. These are among the most powerful propeller turbines ever built.

In the late 60's and early 70's, GE Canada supplied ten propeller turbines rated 104 MW at a design head of 30.1 metres for Manitoba Hydro's Kettle Project and ten rated 100 MW at 24.4 metres for their Long Spruce Project. The extremely successful operating record of these machines has

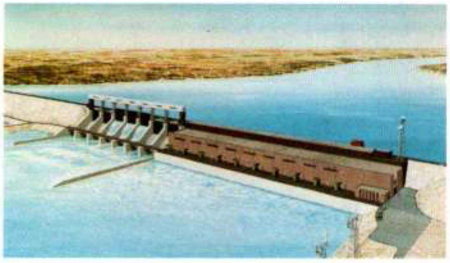
A 44.2 MW uprated replacement Francis runner for Hydro-Québec's Beauharnois Power Station.

One of ten 100 MW propeller turbines for Manitoba Hydro's Long Spruce Project. These units were the forerunner of the propeller turbines for the Limestone Project.



Achievements . . . the foundation of the future (cont'd)

Ten GE Canada propeller turbines rated 125 MW at a design head of 27.6 metres will be installed in Manitoba Hydro's Limestone Generating Station on the Nelson River.



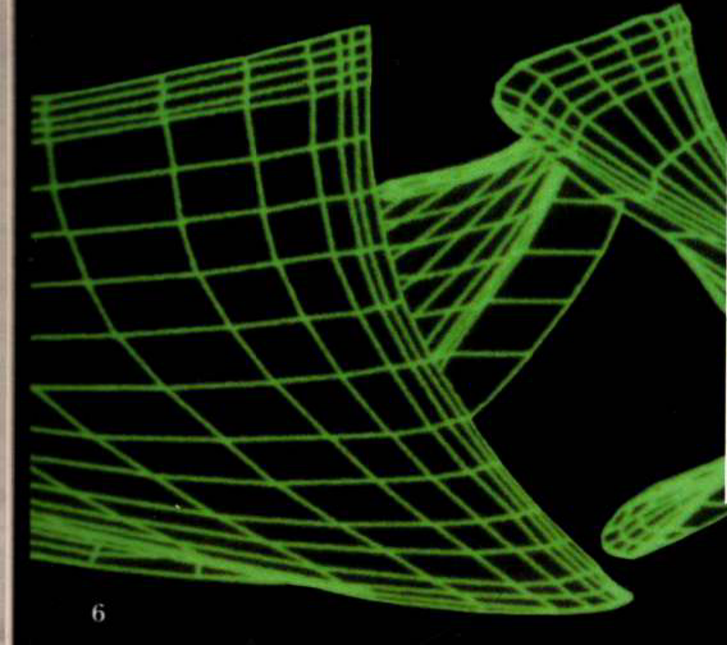
resulted in a contract from Manitoba Hydro to supply an additional ten turbines for their Limestone Project. These units will each have a rating of 125 MW at a design head of 27.6 metres.

More recently, the Company has received a contract for the engineering, supply and installation of eight propeller turbines for the La Grande 1 Project of the Société d'énergie de la Baie James. These turbines, rated 114 MW under a head of 27.5 metres, are scheduled for commissioning in 1994-5.

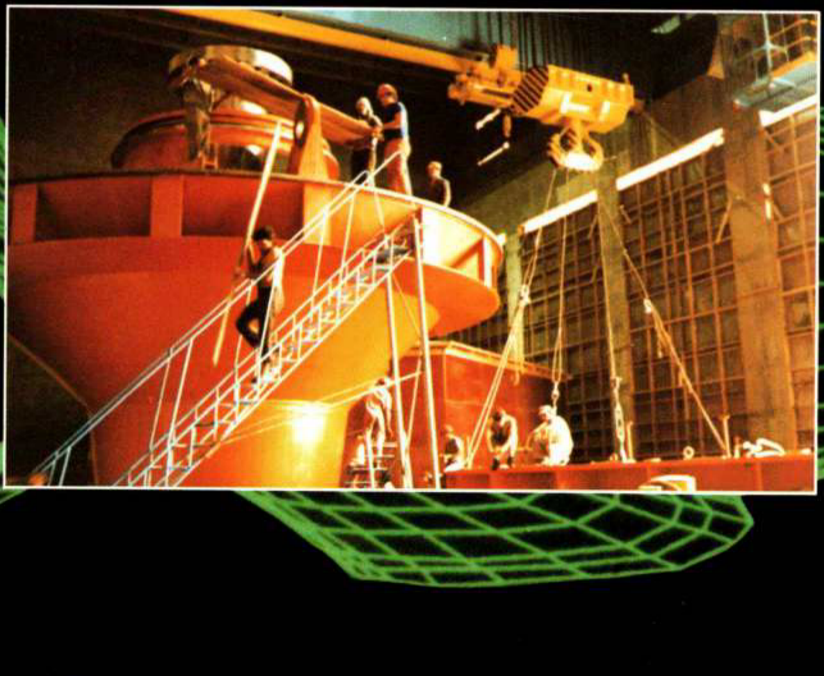
Kaplan Turbines

The Company's extensive experience in propeller turbines paved the way for their entry into the Kaplan turbine field in the late 1940's when many stations requiring this type of machine were being built. Early successes included fourteen 44 MW units built for Hydro-Québec's Carillon powerhouse on the Ottawa River and three 104 MW units installed

Pump turbine runner for US Army Corps of Engineers' Richard B. Russell Power Station.



This 110 MW Kaplan turbine for Moxoto Power Station in Brazil is among the largest of its type in the world.



Shop assembled manifold for the Idukki II Project of the Kerala State Electricity Board in India.

GE Canada Kaplan turbines rated 104 MW at a design head of 33.5 metres are installed in the Mactaquac Station of the New Brunswick Electric Power Commission.

at the Mactaquac station of the New Brunswick Electric Power Commission. The most recent domestic Kaplan turbine project is for the manufacture and installation of two 230 MW turbines operating under a head of 38.4 metres for the Brisay Project of the Société d'énergie de la Baie James. These units are scheduled for commissioning in 1993.

GE Canada has also produced a number of Kaplan turbines for the international market. These include two 6.7 MW units for the Shadiwal Powerhouse in West Pakistan, ten 89 MW units installed at Wanapum in the USA, and four 110 MW units for the Moxoto hydro project in Brazil. The latter, operating at a design head of 22 metres, are among the world's largest Kaplan turbines. Also produced for Brazil were two 73 MW units for the Passo Real and four 103 MW units for the Volta Grande projects.

The most recent international program is a joint undertaking with Voith Hydro, USA. GE Canada and Voith will design Kaplan turbines for the massive Yacyreta Project in Argentina with manufacturing to be shared by Canada, USA, Argentina and Paraguay. Twenty units each rated 138 MW at 21.3 metres head will be produced. This project will be one of the world's largest installations of Kaplan turbines.

Pelton Turbines

GE Canada's past achievements with Pelton turbines are best exemplified by the four vertical, four-jet units each rated 123 MW under a head of 762 metres built for the Aluminum Company of Canada Kemano Plant in British Columbia. More recently, GE Canada in co-operation with a European turbine manufacturer designed and built three vertical six-jet Pelton turbines rated at 134 MW under a head of 660 metres for the Idukki II Project in India. Pelton turbines with lower ratings have also been produced for installation in Brazil, Bolivia and India.

Pump Turbines

GE Canada's extensive experience in conventional turbines can be readily applied to pump turbines. The most recent project of this type is the four 78 MW reversible pump turbines designed in cooperation with a European manufacturer for the US Army Corps of Engineers, Richard B. Russell Project, on the Georgia-South Carolina border. These machines have a runner diameter of 5.8 metres, ranking them among the largest in the world.

GE Canada maintains a test facility for pump turbines and has undertaken extensive research and development in this field.

Kaplan turbine runner for the modernization program at the City of Talahassee's Jackson Bluff Power Station.

This Pelton turbine runner, one of three 123 MW units built for the Aluminum Company of Canada, operates under a head of 762 metres, the highest in Canada.

Perfecting the art of turbine design

Integrated Computer-Aided Design and Manufacturing

Virtually all functions of turbine design, development and manufacturing have been integrated into a single computer-controlled process at the GE Canada Lachine Plant. By utilizing a common database for design engineering, drafting, model fabrication and for manufacture of full size components, GE Canada has achieved a significant reduction in the time required to design and manufacture a turbine. Computer-aided design and manufacturing has also enabled GE Canada to achieve a more accurate rendering of the turbine design data into model and prototype hardware with resultant improvements in performance.

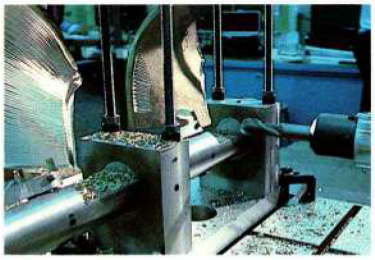
State-of-the-Art Computer Design Technologies

Several specific computer technologies have been implemented to enable GE Canada to produce quality custom designs to meet customer requirements and to integrate the design and manufacturing functions.

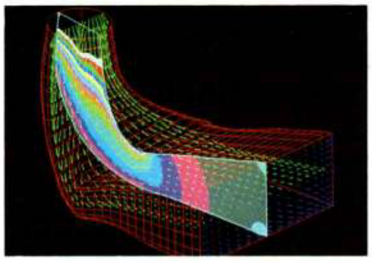
- A relational database of all tested model designs and their corresponding test results provides rapid access to historical data to establish trends and to generate a high quality initial hydraulic design for further analysis and testing.
- A parametric interactive design approach captures design intent and allows for rapid and automatic design regeneration in response to changes in design parameters.
- Solid modelling of all major turbine components facilitates calculation of weights, checking of interferences, and examination of other characteristics.
- Finite element analysis of all major structural components ensures integrity and long life for these key items.
- 3D viscous turbulent flow analysis is performed on major components to determine losses and anomalous flow patterns at the design stage.
- Manufacturing drawings are produced by taking views and sections of the solid models. This ensures the integrity of the drawing information and reduces the time required to produce the drawings.

GE Canada has played a leading role in the application of computer-aided design and manufacturing techniques to hydraulic turbine production.

Endoscope observation of model turbine runner inflow cavitation.



Model turbine runner blades are shaped on a numerically controlled five-axis milling machine.



Velocity vectors and draft tube pressure distribution along the centre plane generated by 3D viscous flow analysis.

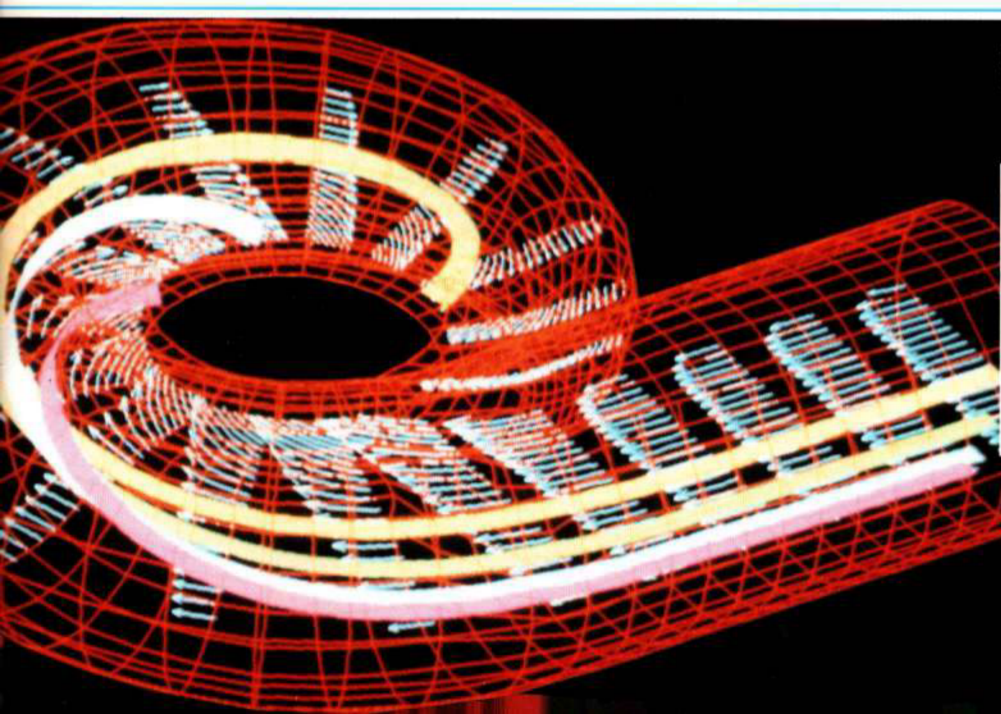
Model turbine components and test stand control panel.

VAXstation

Computer workstation displaying a solid model of a semi-spiral casing viewed from the intake.

Model Manufacturing

The model turbine must be made precisely in accordance with the design data so that the results obtained when it is tested will accurately reflect the performance of the prototype machine. At GE Canada, much of this precision is achieved by numerically controlled machining of the model component shapes utilizing design database information. The remainder is provided by skilled craftsmen with years of experience who carefully hand finish and painstakingly fit and refit each component. The result is a model which hundreds of precedents have proven can be relied upon to provide test data accurately reflecting the performance of the prototype machine.



Hand finishing of model turbine runner blade surfaces.

A group of Francis and Kaplan model runners of various specific speeds developed for testing.

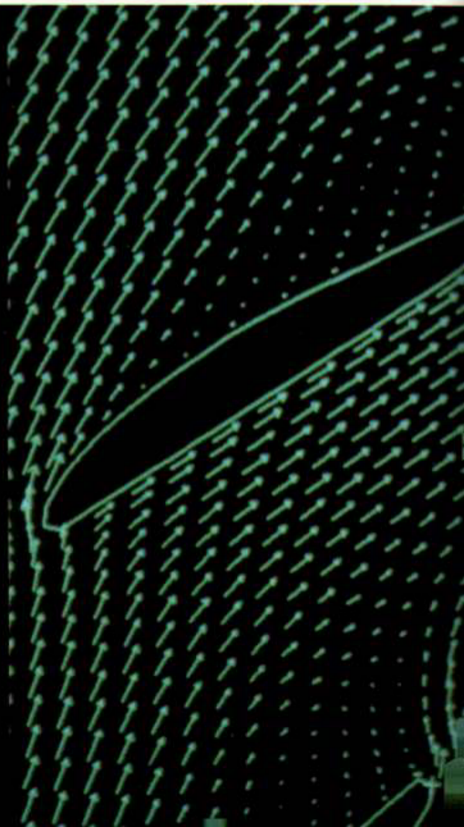
High speed data acquisition equipment for stability and mechanical behavior tests in the hydraulic laboratory.

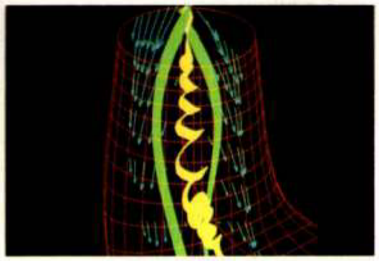
World-Class Model Testing Facilities

Model testing is carried out in GE Canada's well-equipped Hydraulic Laboratory, a facility recognized as world-class in the industry and the only one of its kind in Canada. The results obtained from extensive tests on the model enable design engineers to predict the performance of the full size machine and indicate where changes can be made to optimize the design. The accuracy and reliability of the information obtained during model testing has been proven by independent laboratories during contractual model acceptance tests.

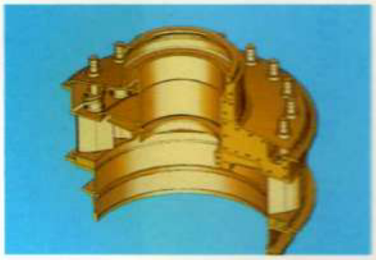
The facilities consist of two test stands, one of which has been specially designed to accommodate pump turbine applications. Both are equipped with sophisticated instrumentation and control systems, automatic data

Video system for observation of cavitation and flow phenomena downstream of the runner.





Draft tube velocity vectors with superimposed particle paths.



Solid modelling of a model tower assembly section.

Solid model of a wicket gate mechanism.

acquisition equipment and a computer for data processing.

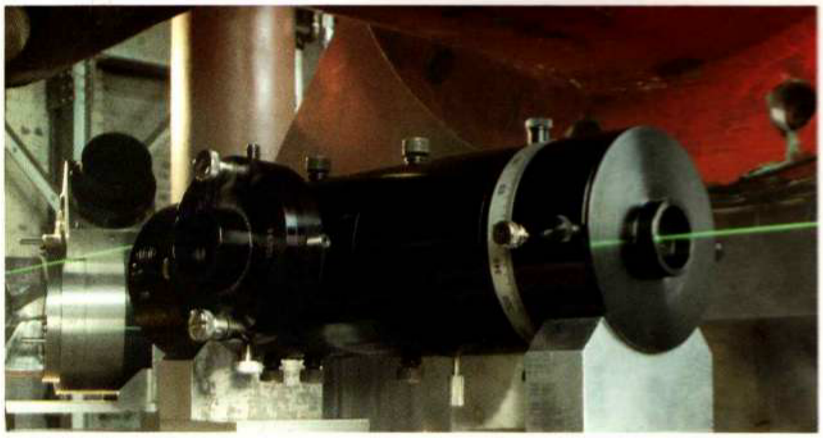
Research

The facilities of the Hydraulic Laboratory are also used for applied research on all aspects of turbine design. A wind tunnel and a water test stand are especially dedicated to the experimental validation of computer programs solving the fundamental equations of fluid flow. In addition, the research group may also draw upon the vast technological resources of the General Electric Company's corporate research facilities in the United States.

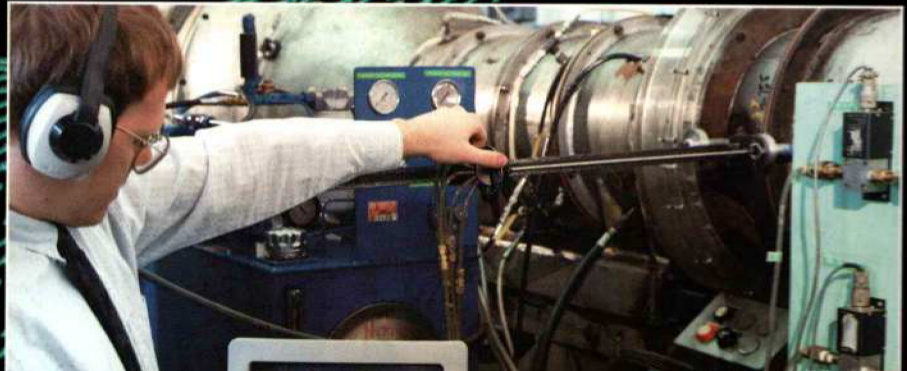
Designing for Offshore Production

GE Canada has pioneered in the design of turbine components specifically intended for assembly or manufacture in the country of installation. For example, the plate steel spiral cases of GE Canada turbines can be produced wherever suitable plate bending facilities are available. The stay ring, to which the spiral case is welded, can be designed so that it requires no machining, allowing it to be produced in locations where there are no machine tools.

For large Francis runners that cannot be shipped in one piece, methods of welding the sections together and machining the completed runner on site have been developed. Similar methods have been devised to assemble the sections of large propeller runners.



Laser doppler velocity equipment designed to measure flow velocities at points between the runner blades. The frequency of light reflected back from microscopic particles in the water is used to determine the water flow velocity.



A 3D pitot probe in a wind tunnel is used to measure the draft tube energy recovery factor.

Manufacturing . . . superb in-house facilities . . . dedicated support for offshore partners

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Canada's extensive turbine design, testing and manufacturing facilities are located on a 15-acre site in Lachine, Québec, a suburb of Montréal.

The fabrication and machine shop consists of five large bays with a total floor area of 18,000 square metres. Support facilities include a crane with a lifting capacity of 250 tons, a heat treating furnace designed specifically for turbine runners, a combined grit-blast and paint enclosure, and numerically controlled plate cutting equipment.

Major machine tools include two state-of-the-art horizontal boring machines, one retrofitted to five-axis numerical control specifically for machining large propeller and Kaplan turbine blades, and a five-axis DNC gantry mill used for contour milling of Francis runner surfaces. These machines are complemented by a large numerically controlled vertical boring mill with a swing of 12.7 metres and a table designed for loads up to 500 tons. Also included in the shop is a wicket gate machining cell, a cluster of the machines necessary to do all machining operations on a wicket gate. The shop is dedicated to the manufacture of hydro components and production equipment has been arranged for an optimum flow of material.

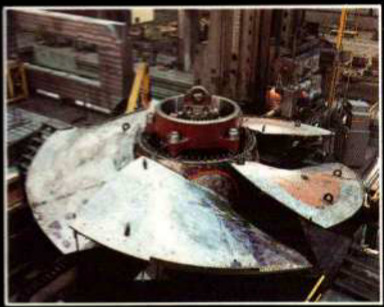
Integrated Computer-Aided Manufacturing

The application of computer technology to turbine component manufacturing has been developed to a fine art at the Lachine Plant. By integrating computer-aided manufacturing as the final stage in a highly computer-based design, model fabrication, full-sized component

Hand finishing of replacement Francis runner after machining.

Five-axis NC machining of prototype blades based on a computerized blade surface definition common with the model ensures a high degree of homology while reducing manufacturing time.

Shop assembly of Kaplan runner to test hub operating mechanism.



Technician uses state-of-the-art ultrasonic equipment for non-destructive tests on welded components.

Machining of a pump turbine head cover assembly on a vertical boring mill.

GE Canada inspector checks the [illegible] of this turbine shaft to en[illegible] machining tolerances are me[illegible]

production process, GE Canada can manufacture complicated turbine components with greater accuracy and in less time than with previous methods, allowing performance guarantees to be increased and costs to be reduced. A continuing effort to improve these techniques will result in even greater productivity gains and machining accuracies in the future.

Craftsmanship

Although complex computers and huge machine tools perform much of the work involved in producing a hydro turbine, craftsmanship still plays an essential role in the success of each project. All operations are closely monitored by skilled and experienced GE Canada personnel to ensure that components have the special characteristics required for turbine service. Both model and prototype runner blade surfaces are finished by hand polishing to achieve the highest possible level of operating efficiency.

There is a proud tradition of craftsmanship at GE Canada, developed over many years of manufacturing. This tradition is evident in every turbine produced.

Quality Assurance

Rigid quality control is applied to all aspects of turbine manufacture. Expert quality assurance staff using state-of-the-art equipment and techniques monitor incoming materials and components and all in-plant and subcontractor workmanship at each step of the fabrication and assembly process. In addition to conventional measuring and testing devices, quality assurance facilities include calibration equipment, a computerized monitoring system and equipment for all forms of non-destructive testing.

All quality assurance at [illegible] GE Canada is per[illegible] accordance with Lev[illegible] of the Canadian Govern[illegible] National Quality Standards Program Z-299. This progra[illegible] covers a wide range of qu[illegible] control functions from sim[illegible] inspection procedures [illegible] mandatory design revie[illegible] provides the strong frame[illegible] required to ensure a con[illegible] high standard of produc[illegible]

The manufacturing facilities at GE Canada's Lachine Plant are dedicated to the production of hydro components.

Assembling a Francis runner.

Support services

Hydro Modernization

A large portion of the research carried out in the Hydraulic Laboratory has been devoted to the development of Francis, propeller and Kaplan turbines with increased power outputs, higher efficiencies and improved cavitation characteristics without increasing the physical size of the runner. A number of utilities have taken advantage of these improvements by installing replacement runners of modern design in older GE Canada turbines. Where the configuration of water passageways permits, new GE Canada runners have also been successfully fitted into turbines originally manufactured by others. Since the cost of these replacement runners is often far exceeded by the revenue gained from the increased turbine output, the modernization program is meeting with great success in both domestic and international markets.

Installation Services

The Company provides Technical Directors to supervise turbine installation at the customer's site. GE Canada Technical Directors are thoroughly familiar with the equipment being supplied, and have experience in solving the problems encountered at remote overseas job sites. They coordinate all aspects of the project and provide technical advice to customer and/or installation contractor personnel as required.

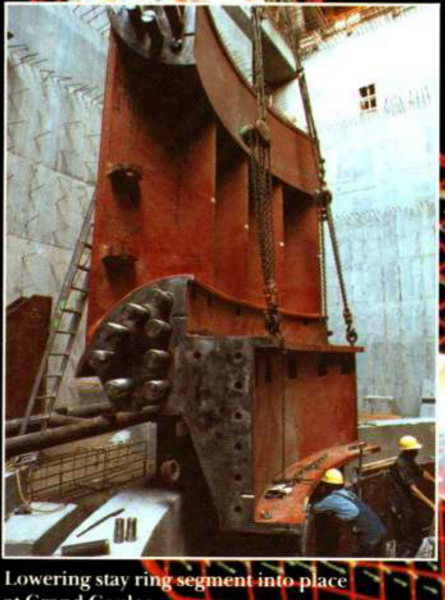
Project Management

GE Canada has the experience and expertise to manage all aspects of a hydroelectric project from initial design through customer acceptance of the installed equipment. This can include transportation arrangements, sourcing of components from the country of installation, utilization of local labour for installation, training of personnel and other special requirements.

Technology Transfer

GE Canada has developed a number of very successful technology transfer agreements which have enabled manufacturers in other countries to expand their activities in the hydroelectric power generation field. The first agreement was made in the 1960's with a Brazilian manufacturer with no previous experience in hydro power equipment. Initially, GE Canada provided facilities and training in all phases of manufacturing. Later, design technology was transferred and now the company is independently designing and manufacturing hydro generators and, with continuing support from GE Canada, hydraulic turbines. Similar agreements have been established with manufacturers in Canada, Colombia, India and China and others are being negotiated.

Hydro modernization programs have resulted in increases as high as 38 percent in turbine output and 5% in efficiency.



Lowering stay ring segment into place at Grand Coulee.

GE Canada's in-depth project management experience has been acquired through successful handling of many hundreds of projects in over 40 countries.

CN 670002
FWS CAPY 280000
LD LMT 250000
LT WT 127200

Related products

Spherical Valves

GE Canada has been designing and building spherical valves for almost four decades. Among the largest produced are the 3.35 metre diameter units operating under a 282 metre head at the Aluminum Company of Canada's Chute-des-Passes Project in Québec. Even larger are the 3.66 metre units designed to operate under a head of 154 metres for Hydro-Québec's Manicouagan 5 Project. Other GE Canada spherical valves in various sizes are in service in a wide variety of applications at several locations around the world.

Ring Gates

Ring gates replace the conventional butterfly or spherical penstock shutoff valves. They provide a number of benefits, the most significant being substantially lower overall powerhouse costs, and reduced installation and maintenance costs. They do not adversely affect turbine efficiency.

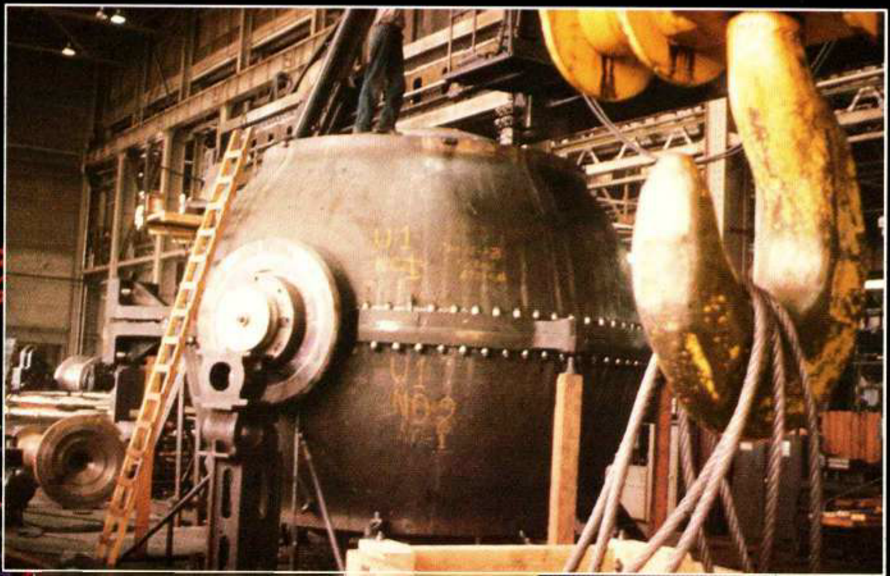
Ring gates were pioneered by GE Canada and Hydro-Québec in the 1960's. Four units with diameters of 6.3 metres and operating under heads of 144 metres were installed at Outardes 3 Power Station and six with diameters of 7 metres and operating under heads of 94.2 metres were installed in Manicouagan 3. Eight of the largest ring gates in the world were later installed in La Grande 2 Power Station in the James Bay power complex. These gates weigh 34 tons, have an outside diameter of 7.6 metres and operate under a head of 137 metres.

Hydroelectric Generators

GE Canada has been at the forefront of hydroelectric generator design and manufacturing technology since the turn of the century. In recent years, both the world's highest rated water-cooled machines, the 826 MVA units for Grand Coulee, USA, and the world's highest rated air-cooled machines, the 805 MVA units for Guri 2 in Venezuela, were built by GE Canada. In 1979, the hydroelectric generator operations of GE Canada and the General Electric Company of the USA joined forces. Together, they have manufactured or have on order hydroelectric generators with a total generating capacity of over 90,000,000 KVA . . . more than any other company in the world.

GE Canada has the world mandate for design and manufacture of hydraulic turbines and hydroelectric generators within the GE organization.

Spherical valve for Hydro-Québec's Manicouagan 5 Project.



Stepped spillway at the La Grande 2 Powerhouse of the Société d'énergie de la Baie James. GE Canada supplied turbines, ring gates and generators for this project.

GE Canada

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